Memphis International Airport

Capacity Enhancement Plan Update

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October 1997

Prepared jointly by the U.S. Department of Transportation, Federal Aviation Administration, the Memphis-Shelby County Airport Authority, and the airlines and general aviation serving Memphis, Tennessee.

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Executive Summary

Airport Capacity Design Teams are formed to address capacity problems at airports with significant flight delays. The teams are composed of FAA representatives from the Office of System Capacity (ASC), the Technical Center, Air Traffic, and the appropriate FAA Region; airport operators; airlines; and other aviation industry representatives. The goal of the Design Team is to identify and evaluate proposals to increase airport capacity, improve airport efficiency and reduce aircraft delays while maintaining or improving aviation safety.

Memphis International Airport (MEM) is the 39th busiest airport in the country when ranked by 1995 passenger enplanements. In the past decade, MEM has experienced steady, sustained growth. Enplanements at MEM rose from 2,413,000 in 1983 to 4,223,864 in 1995, an increase of over 75 percent. MEM's total aircraft operations (takeoffs and landings) reached 356,294 in 1995, an increase of more than 22 percent over the 292,000 aircraft operations the airport handled in 1983. MEM has the distinction of being ranked the number one air cargo airport in the world for the fifth consecutive year, according to a survey conducted by Airports Council International. It is noteworthy that, during 1996, a total of 1,933,000 metric tons of cargo was moved through MEM. Continued traffic growth, according to FAA projections, will place Memphis on the list of airports experiencing over 20,000 hours of annual delay in 2004, if no improvements are made.

In May, 1995, the FAA formed an Airport Capacity Design Team for MEM to update the 1988 Capacity Enhancement Plan in view of the fact that a new runway was to be commissioned in December 1996 and, shortly thereafter, an existing runway would be closed for reconstruction. The Design Team considered additional improvements to enhance MEM's capacity; updated and validated computer model inputs and capacity and delay estimates; and provided input to the MEM Master Plan update. A major factor influencing the Design Team's deliberations was the cost benefit of any alternative recommended for implementation.

Selected improvements identified by the Design Team were tested using computer models developed by the FAA to quantify the benefits provided. Different levels of activity were chosen to represent growth in aircraft operations in order to compare the merits of each action. These annual activity levels are referred to throughout this report as:

- Baseline — 360,000 operations.
- Future 1 — 456,000 operations.
- Future 2 — 534,000 operations.

The process determined the technical merits of each alternative action and its potential to increase capacity and reduce delays. Following the evaluation process, the Design Team recommended several improvements which, if implemented, will increase capacity and improve efficiency. The most significant of these for the near term are:

- Extend Runway 18C/36C to the south to 11,100 ft to accommodate non-stop long range flights.
- During reconstruction of Runway 18R/36L, operate Taxiway M as an air carrier runway with arrivals and departures in north and south flow during visual flight rules (VFR) only.
- Extend Taxiway N to the full length of existing Runway 18R/36L to provide improved access to Runway 36L and provide temporary service to Taxiway M while being utilized as an active runway.

Figure 1. Memphis International Airport

Figure 1. Memphis International Airport

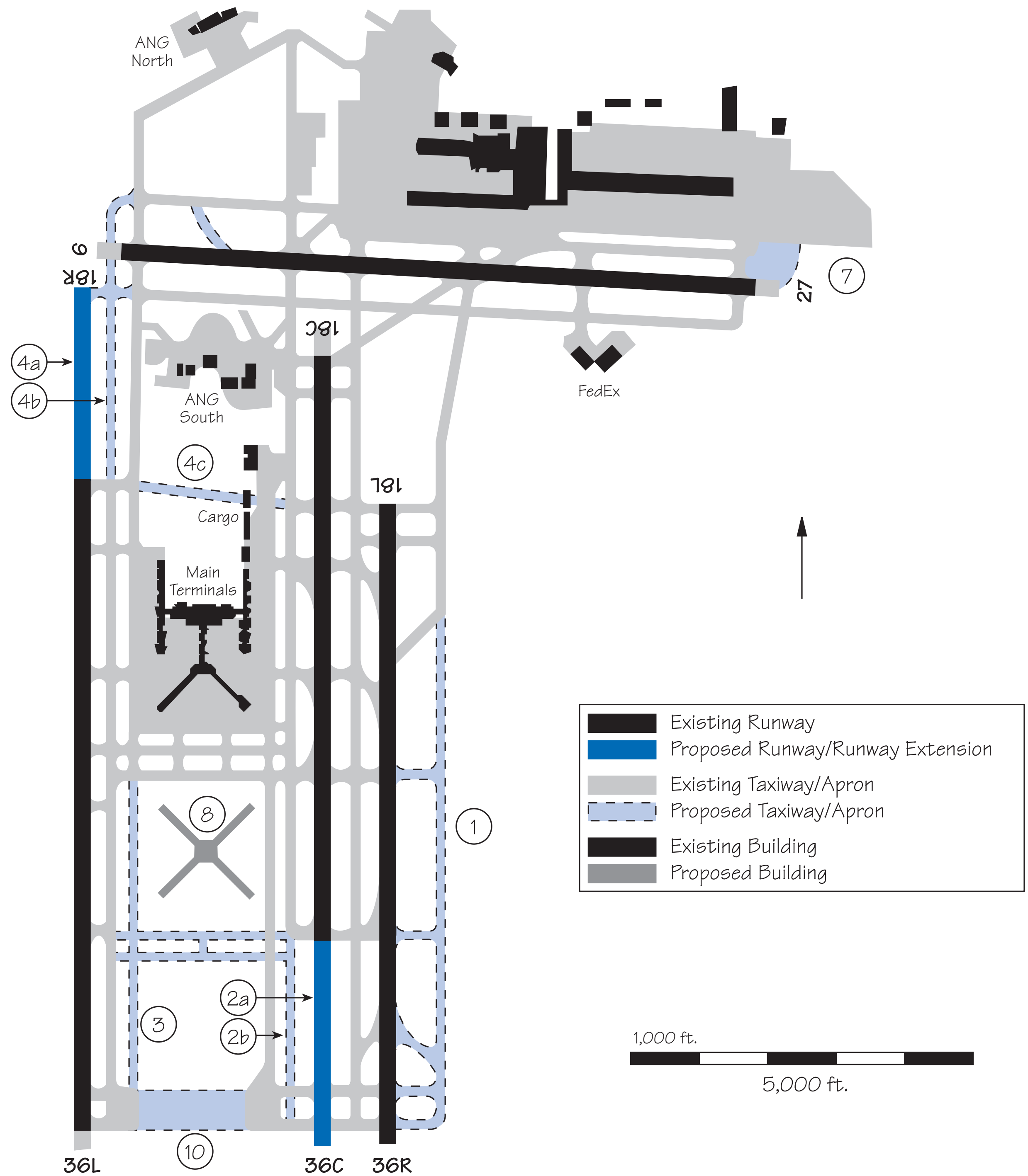


Figure 2. Capacity Enhancement Alternatives and Annual Delay Savings

		Estimated Annual Delay Savings (in hours and millions of 1995 dollars)			
		Baseline (360,000)	Future 1 (456,000)	Future 2 (534,000)	Costs $M
Airfield Improvements					
1.	Extend Outer Taxiway Y East of and Parallel to Runway 18L/36R	170/$.41	1,830/$5.49	2,810/$9.95	$19.2
2a.	Extend Runway 18C/36C to the South to 11,100' to Accommodate Non-stop (Long Range) Flights		*		$69.2
2b.	Extend Taxiway C to Extended Runway 36C's End		*		$5.3
3.	Extend Taxiway N to the Full Length of Existing Runway 18R/36L to Provide Improved Access to Runway 36L	10/$.03	770/$2.31	3,010/$10.66	$10.0
4a.	Extend Runway 18R/36L to Taxiway A		*		$350.0
4b.	Extend Taxiway M to Taxiway V	830/$1.99	1,710/$5.12	8,210/$29.06	$25.0
4c.	Construct a New Taxiway M7 from Exit M7 to Taxiway C at Exit D	00/$00	680/$2.05	4,230/$14.98	$100.0
5.	High Speed Exits in Both Flow Directions on Runways 18R/36L, 18C/36C, 18L/36R and 9/27 with Reduced Occupancy Times (50 secs) to Support Reduced Longitudinal Spacing (Item 24). Additionally, Consider High Speed Exits on Runway 18L/36R on Both Sides (East and West) of the Runway	210/$.50	760/$2.27	2,550/$9.01	$6.7
6.	During Reconstruction of Runway 18R/36L:**				
6a.	Operate Extended Taxiway N as a 5,000' Commuter/GA Runway in VFR Only. Use for Arrivals in North Flow and Departures in South Flow.	530/$1.28	4,270/$12.8	7,240/$25.61	$.05
6b.	Operate Taxiway M as a 9,000' Air Carrier Runway - ARR and DEP in Both North and South Flows in VFR Only (Aircraft Limited to Maximum Wingspan of 108 ft (B-727-200))	1,280/$3.07	12,680/$38.02	31,380/$111.05	$2.0
7.	Construct By-pass Taxiway on North Side at Runway 27 end.	00/$00	880/$2.65	2,930/$10	$8.0
8.	Terminal Expansion		*		$150.0
9.	Develop Area (500 Acres) East of Runway 18L/36R for Cargo and Maintenance Facilities		*		$20.0
10.	Establish Deicing Facility Between Runways 36L and 36C at South End on Crossover Taxiways H and R		*		$26.0
11.	Establish Departure Staging Areas (Staging of 2,3,4, or 5 Aircraft) at All Runway Ends		*		$5.0 to $12.5
Facilities and Equipment Improvements					
12.	Category IIIc, Less Than 600' RVR Approaches - Runways 36R and 36L		*		†
13.	Precision Runway Monitor (PRM), Final Monitors/Aids (FMA):***	1,410/$3.4	4,240/$12.73	6,230/$22.06	7.0
14.	Integrated Terminal Weather System (ITWS)		*		†
15.	Wake Vortex Advisory System (WVAS)				
15 a.	No Wake Vortices Detected 50% of the time	230/$.54	1,320/$3.96	3,200/$11.30	†
15 b.	No Wake Vortices Detected 100% of the time	450/$1.07	2,640/$7.92	6,390/$22.60	†
16.	Center TRACON Automation System (CTAS)		*		

Figure 3. Capacity Enhancement Alternatives Studied and Recommended Actions

		Action	Time Frame
Airfield Improvements			
1.	Extend Outer Taxiway Y East of and Parallel to Runway 18L/36R	Recommended	Baseline
2a.	Extend Runway 18C/36C to the South to 11,100' to Accommodate Non-stop (Long Range) Flights	Recommended	Baseline
2b.	Extend Taxiway C to Extended Runway 36C's End	Recommended	Baseline
3.	Extend Taxiway N to the Full Length of Existing Runway 18R/36L to Provide Improved Access to Runway 36L	Recommended	Baseline
4a.	Extend Runway 18R/36L to Taxiway A	Recommend Further Study	
4b.	Extend Taxiway M to Taxiway V	Recommend Further Study	
4c.	Construct a New Taxiway M7 from Exit M7 to Taxiway C at Exit D	Recommend Further Study	
5.	High Speed Exits in Both Flow Directions on Runways 18R/36L, 18C/36C, 18L/36R and 9/27 with Reduced Occupancy Times (50 secs) to Support Reduced Longitudinal Spacing (Item 24), Additionally, Consider High Speed Exits on Runway 18L/36R on Both Sides (East and West) of the Runway	Recommended	Baseline
6.	During Reconstruction of Runway 18R/36L:		
6a.	Operate Extended Taxiway N as a 5,000' Commuter/GA Runway in VFR Only. Use for Arrivals in North Flow and Departures in South Flow.	Not Recommended	
6b.	Operate Taxiway M as a 9,000' Air Carrier Runway - ARR and DEP in Both North and South Flows in VFR Only (Aircraft Limited to Maximum Wingspan of 108 ft (B-727-200))	Recommended	Baseline
7.	Construct By-pass Taxiway on North Side at Runway 27 End	Recommended	Baseline
8.	Terminal Expansion	Recommend Further Study	
9.	Develop Area (500 Acres) East of Runway 18L/36R for Cargo and Maintenance Facilities	Recommended	Baseline
10.	Establish Deicing Facility Between Runways 36L and 36C at South End on Crossover Taxiways H and R	Recommended	Future 2
11.	Establish Departure Staging Areas (Staging of 2, 3, 4, or 5 aircraft) at All Runway Ends,	Recommended	Baseline
Facilities and Equipment Improvements			
12.	Category IIIc, Less Than 600' RVR Approaches - Runways 36R and 36L	Recommended	Baseline
13.	Precision Runway Monitor (PRM), Final Monitors/Aids (FMA):	Recommended	Baseline
14.	Integrated Terminal Weather System (ITWS)	Recommended	Baseline
15.	Wake Vortex Advisory System (WVAS)	Recommended	Baseline
15a.	No Wake Vortices Detected 50% of the time		
15 b.	No Wake Vortices Detected 100% of the time		
16.	Center TRACON Automation System (CTAS)	Recommended	Baseline

Figure 2. Capacity Enhancement Alternatives and Annual Delay Savings (cont.)

		Estimated Annual Delay Savings (in hours and millions of 1995 dollars)			
		Baseline (360,000)	Future 1 (456,000)	Future 2 (534,000)	Costs $M
Operational Improvements					
17.	Converging Arrivals on 18L, 18R, and 27 Using the Converging Runway Display Aid (CRDA) - With Unrestricted Use of Rwy 27 in VFR		*		n/a
18.	Reduce Longitudinal In-Trail Spacing to 2.5 NM in IFR	790/$1.9	2,410/$7.23	4,940/$17.49	n/a
19.	Simultaneous Parallel Departures on Runways 18R and 18C in Non-visual Conditions (less than 5,000' Ceiling and/or 5 Miles Visibility) Assuming Flight Procedures Allow Departures to Diverge by 15 Degrees Immediately After Takeoff	60/$.15	150/$.44	300/$1.04	n/a
20.	Triple Simultaneous Parallel Departures in South Flow:				
20a.	Rwys 18R, 18C and 18L Without Rwy 27 (w/o Noise Abatement)	(3,730/$8.94)	(13,550/$40.65)	(33,520/$118.66)	n/a
20b.	Rwys 18R, 18C and 18L With Rwy 27 (w/o Noise Abatement)	310/$.76	4,460/$13.37	2,310/$8.17	n/a
21.	Runway Operations During Reconstruction of Runways 18R/36L, 18C/36C, and 9/27:				
21a.	Runway 18C/36C Closed, Runways 18R/36L, 18L/36R and 9/27 Operational	(1,060/$2.54)	(6,530/$19.6)	(14,420/$51.06)	n/a
21b.	Runway 18R/36L Closed, Runways 18C/36C, 18L/36R and 9/27 Operational	(10,950/$26.27)	(41,820/$125.45)	(93,320/$330.34)	n/a
21c.	Runway 18R/36L Closed, Runways 18C/36C, 18L/36R and 9/27 Operational with :**				
	i. Taxiway N as a Temporary Commuter/GA Rwy in VFR Only (Arr North Flow, Dep South Flow)	530/$1.28	4,270/$12.8	7,240/$25.61	n/a
	ii. Taxiway M as a Temporary Air Carrier Runway - ARR and DEP in North and South Flow in VFR Only (Aircraft Limited to Maximum Wingspan of 108 ft (B-727-200))	1,280/$3.07	12,680/$38.02	31,380/$111.05	n/a
21d.	Runway 9/27 Closed, Runways 18R/36L, 18C/36C, and 18L/36R Operational	(7,130/$17.10)	(26,000/$78.01)	(59,970/$212.3)	n/a
21e.	Runway 18C/36C and 18R/36L Closed, Runways 9/27 and 18L/36R Operational	(23,040/$55.29)	(89,700/$269.1)	(154,400/$546.58)	n/a
User or Policy Improvements					
22.	Uniformly Distribute Scheduled Commercial Operations Within the Hour.		*		n/a
23.	Enhancement of the Reliever and GA Airport System		*		n/a

Note: The delay savings benefits of these alternatives are not necessarily additive and are based on improvements to the existing airfield unless otherwise noted. Numbers in parenthesis are costs.

* No delay savings were estimated for these alternatives. Descriptions of these improvements are in Section 2 - Capacity Enhancement Alternatives.

** The delay savings benefits of these improvements are based on a comparison of their delay costs with the delay cost of alternative 21b.

*** The delay savings benefits are based on a comparison of the delay costs with and without the PRM, assuming Runway 18L/36R being out of service. However, it is not expected that Runway 18L/36R will be out of service for any extended period of time. Please note that the delay savings are computed on an annual basis.

† Project costs unavailable.

n/a Project costs not applicable.

Figure 3. Capacity Enhancement Alternatives Studied and Recommended Actions (cont)

		Action	Time Frame
Operational Improvements			
17.	Converging Arrivals on 18L, 18R, and 27 Using the Converging Runway Display Aid (CRDA) - With Unrestricted Use of Rwy 27 in VFR	Recommended	Baseline
18.	Reduce Longitudinal In-Trail Spacing to 2.5 NM in IFR	Recommended	Baseline
19.	Simultaneous Parallel Departures on Runways 18R and 18C in Non-visual Conditions (less than 5,000' Ceiling and/or 5 Miles Visibility) Assuming Flight Procedures Allow departures to Diverge by 15 Degrees Immediately after Takeoff	Recommended	Baseline
20.	Triple Simultaneous Parallel Departures in South Flow:		
20a.	Rwys 18R, 18C and 18L Without Rwy 27 (w/o Noise Abatement)	Not Recommended	
20b.	Rwys 18R, 18C and 18L With Rwy 27 (w/o Noise Abatement)	Recommend Further Study	
21.	Runway Operations During Reconstruction of Runways 18R/36L, 18C/36C, and 9/27:	*	
21a.	Runway 18C/36C Closed, Runways 18R/36L, 18L/36R and 9/27 Operational	*	
21b.	Runway 18R/36L Closed, Runways 18C/36C, 18L/36R and 9/27 Operational	*	
21c.	Runway 18R/36L Closed, Runways 18C/36C, 18L/36R and 9/27 Operational with:	*	
	i. Taxiway N as a Temporary Commuter/GA Rwy in VFR Only (Arr North Flow, Dep South Flow)	*	
	ii. Taxiway M as a Temporary Air Carrier Rwy - Arr & Dep in North and South Flow in VFR Only. (Aircraft Limited to Maximum Wingspan of 108 ft (B-727-200))	*	
21d.	Runway 9/27 Closed, Runways 18R/36L, 18C/36C, and 18L/36R Operational	*	
21e.	Runway 18C/36C and 18R/36L Closed, Runways 9/27 and 18L/36R Operational	*	
User or Policy Improvements			
22.	Uniformly Distribute Scheduled Commercial Operations Within the Hour.	Not Recommended	
23.	Enhancement of the Reliever and GA Airport System	Recommended	Baseline

* This improvement included for informational and construction planning purposes only.

Section 1

Introduction

Background

In 1985, the FAA initiated a renewed program of Airport Capacity Design Teams at various major air carrier airports throughout the U.S. Each Design Team identifies and evaluates alternative means to enhance existing airport and airspace capacity to handle future demand and works to develop a coordinated action plan for reducing airport delay. Over 40 Airport Capacity Design Teams have either completed their studies or have work in progress.

The first Airport Capacity Design Team for Memphis International Airport completed its study in December 1988. The Design Team was comprised of representatives of the Federal Aviation Administration, the Memphis-Shelby County Airport Authority, and aviation industry groups with interests at MEM. Recommendations for increasing capacity at MEM contained in the December 1988 report have been, or are in the process of being, completed.

Memphis International Airport

Memphis International Airport is the 39th busiest airport in the country when ranked by 1995 passenger enplanements. In the past 12 years, MEM has experienced steady, sustained growth. Enplanements at MEM rose from 2,413,000 in 1983 to 4,223,864 in 1995, an increase of over 75 percent. MEM's total aircraft operations (takeoffs and landings) reached 356,294 in 1995, an increase of more than 22 percent over the 292,000 aircraft operations the airport handled in 1983.

Based in Memphis, Federal Express (FedEx), the world's largest air express transportation company, has shown steady increases in activity over the past ten years and their continued international expansion assures MEM's air cargo business will continue to grow. FedEx delivers more than two million packages to over 200 countries each business day. This activity keeps MEM active twenty-four hours a day. Attributed primarily to FedEx, MEM had the distinction of being ranked the number one air cargo airport in the world for the fifth consecutive year, according to a survey conducted by Airports Council International. It is noteworthy that, during 1996, 1,933,000 metric tons of cargo were moved through MEM.

MEM is one of three regional hubs utilized by Northwest Airlines. In June 1996, Northwest/KLM celebrated the first anniversary of its initial non-stop, intercontinental flight between Memphis and Amsterdam by increasing the number of flights from four a week to daily service. This link is a vital tool in enhancing Memphis' position in international tourism and commerce. In its one year of service, more than 18,000 passengers, filling 71 percent of available seats, and approximately five million pounds of cargo have flown from Memphis to Amsterdam.

Memphis International Airport is owned and operated by the Memphis-Shelby County Airport Authority. The airport is the principal air carrier airport serving a 3,000 square mile area defined as the Memphis Metropolitan Statistical Area (MMSA), comprising Shelby, Fayette, and Tipton Counties in Tennessee, Desoto County in Mississippi, and Crittenden County in Arkansas. According to the latest census, the current population of MMSA exceeds one million. Shelby County's population represented 81% of the total MMSA and increased by 4.7% from 1990 to 1995. From 1995 to 2005, the population of the MMSA is forecast to increase 6.1% to approximately 1.13 million. The MMSA accounts for approximately 80% of the passengers originating their air journeys at MEM. The airfield has four runways:

- Runway 18R/36L is 9,300 feet long and 150 feet wide.
- Runway 18C/36C is 8,400 feet long and 150 feet wide.
- Runway 18L/36R is 9,000 feet long and 150 feet wide.
- Runway 9/27 is 8,900 feet long and 150 feet wide.

In the future, Runway 18C/36C will be extended to 11,100 feet. All four runways will accommodate all classes of aircraft defined in this report.

Memphis Airport Capacity Design Team

A second Airport Capacity Design Team for Memphis International Airport was formed in May 1995. This MEM Design Team was formed to update the 1988 Capacity Enhancement Plan in view of the fact that a new runway was to be commissioned in December of 1996 and shortly thereafter, the existing runways would be shut down for reconstruction. Further, the Team considered additional improvements to enhance MEM's capacity; updated and validated computer model inputs and capacity and delay estimates; and provided input to the MEM Master Plan update. Those alternatives which were considered are listed in this report. The purpose of the process was to determine the technical merits of each alternative action and its impact on capacity. Additional studies will be needed to assess environmental, socioeconomic, or political issues associated with these actions.

This report has established benchmarks for development based upon traffic levels and not upon any definitive time schedule, since actual growth can vary from projections year to year. As a result, the report should retain its validity until the highest traffic level is attained regardless of the actual dates this traffic level occurs.

A Baseline of 360,000 annual aircraft operations (takeoffs and landings) was established. Two future traffic levels, Future 1 and Future 2, were established at 456,000, and 534,000 annual aircraft operations respectively, based on Design Team consensus of potential traffic growth at Memphis International. If no improvements are made at MEM, annual delay levels and delay costs are expected to increase from an estimated 10,640 hours and $25.54 million at the Baseline activity level to 33,670 hours and $101.01 million by the Future 1 demand level and 64,030 hours and $226.66 million by Future 2.

The Design Team studied various proposals with the potential for increasing capacity and reducing delays at MEM. The improvements evaluated by the Design Team are delineated in Figure 2 and described in some detail in Section 2, Capacity Enhancement Alternatives.

Objectives

The major goal of the Design Team was to identify and evaluate proposals to increase airport capacity, improve airport efficiency, minimize delays during reconstruction of runways, and reduce aircraft delays. In achieving this objective, the Design Team:

- Assessed the current airport capacity;
- Examined the causes of delay associated with the airfield, the immediate airspace, and the apron and gate-area operations; and
- Evaluated capacity and delay benefits of alternative airfield improvements, facilities and equipment improvements, operational improvements, and user or policy improvements.

Scope

The Design Team limited its analyses to aircraft activity within the terminal area airspace and on the airfield. They considered the operational benefits of the proposed airfield improvements, but did not address environmental, socioeconomic, or political issues regarding airport development. These issues need to be addressed in future airport planning studies, and the data generated by the Design Team can be used in such studies.

Methodology

The Design Team, which included representatives from the faa, the Memphis-Shelby County Airport Authority, and various aviation industry groups (see Appendix A), met periodically for review and coordination. The Design Team members considered capacity improvement alternatives proposed by the FAA's Office of System Capacity, Technical Center, and Regional Aviation Capacity Program Manager, and by other members of the Team. Alternatives that were considered practicable were developed into experiments that could be tested by simulation modeling. The Design Team validated the data used as input for the simulation modeling and analysis and reviewed the interpretation of the simulation results. The data, assumptions, alternatives, and experiments were continually reevaluated, and modified where necessary, as the study progressed. A primary goal of the study was to develop a set of recommendations for capacity enhancement, complete with planning and implementation time horizons.

Initial work consisted of gathering data and formulating assumptions required for the capacity and delay analysis and modeling. Where possible, model inputs were based on actual field observations at MEM. Proposed improvements were analyzed in relation to current and future demands with the help of FAA computer models, the Airfield Delay Simulation Model (ADSIM), and the Runway Delay Simulation Model (RDSIM). Appendix B briefly explains the models.

The simulation models considered air traffic control procedures, airfield improvements, and traffic demands. Airfield configurations were prepared from present and proposed airport layout plans. Various configurations were evaluated to assess the benefit of projected improvements. Field derived data, air traffic control procedures, and system improvements were used to determine the aircraft separations utilized for the simulations under both visual flight rules (VFR) and instrument flight rules (IFR) operations

Aircraft fleet mix and schedule assumptions were derived from Official Airline Guide data, historical data, and Design Team and other forecasts. Aircraft volume, mix, and peaking characteristics were considered for each of the three different demand forecast levels (Baseline, Future 1, and Future 2). From this, annual delay estimates were determined based on implementing various improvements. These estimates took into account historic variations in runway configuration, weather, and demand. The annual delay estimates for each configuration were then compared to identify delay reductions resulting from the improvements. Following the evaluation, the Design Team developed a plan of recommended alternatives for consideration.

Section 2

Capacity Enhancement Alternatives

Introduction

The capacity enhancement alternatives are categorized and discussed under the following headings:

- Airfield Improvements
- Facilities and Equipment Improvements
- Operational Improvements
- User or Policy Improvements

Figure 1 shows the current layout of the airport, plus the airfield improvements considered by the Design Team.

Figure 2 lists the capacity enhancement alternatives evaluated by the Design Team and presents the estimated annual delay savings benefits for selected improvements. The annual savings are given for the Baseline, Future 1, and Future 2 activity levels which correspond to annual aircraft operations of 360,000, 456,000, and 534,000 respectively. Please note that the delay savings benefits reflected in Figure 2 are not necessarily additive.

Figure 3 presents the recommended action and suggested time frame for each capacity enhancement alternative considered by the Design Team.

Airfield Improvements

1. Extend Outer Taxiway Y East of, and Parallel to, Runway 18L/36R.

This will be a full-length, 100-foot wide taxiway serving Runway 36R as well as airfield development on the east side of the airport. This portion will extend southward from Taxiway Y to the threshold of Runway 36R. This will result in parallel taxiways on each side of Runway 18L/36R allowing directional flows to and from the runway and providing greater flexibility for movement of aircraft on the ground.

The estimated project cost is $19.2 million.

Annual delay savings would be 170 hours or $0.41 million at the Baseline activity level; 1,830 hours or $5.49 million at Future 1; and 2,810 hours or $9.95 million at Future 2.

2a. Extend Runway 18C/36C to the South to 11,100' to Accommodate Non-stop (Long Range) Flights.

This alternative will provide a longer runway to accommodate operations by maximum loaded aircraft. Currently, reductions in either fuel or cargo loads may have to be made because of shorter runway lengths.

The estimated project cost is $69.2 million.

This alternative provides no direct delay savings benefits, however it enhances the capability of MEM to attract operations requiring non-stop, long range flights.

2b. Extend Taxiway C to Extended Runway 36C's End.

Note: Taxiway C cannot presently be extended further south because of CAT II/III glide slope equipment to be placed on that site. Should GPS or other technology supersede this equipment, then extension of the taxiway full length would be desirable. This extension will provide two parallel taxiways on the west side of Runway 36C and allow the simultaneous flow of aircraft to and from the runway.

The estimated project cost is $5.3 million.

3. Extend Taxiway N to the Full Length of Existing Runway 18R/36L to Provide Improved Access to Runway 36L.

Runway 36L is presently served by only one taxiway. To preclude back-taxi on the runway, a second taxiway is needed to manage queuing problems which develop. This alternative would allow the simultaneous flow of aircraft to and from the runway. Additionally, the second taxiway will serve areas for development between the parallels. The extended Taxiway N may serve as a commuter/GA runway during reconstruction of Runway 18R/36L. If, during reconstruction of Runway 18R/36L, Taxiway M is used as a runway instead, this alternative would allow Taxiway N to serve as a full length parallel taxiway.

The estimated project cost is $10 million.

Annual delay savings would be 10 hours or $0.03 million at the Baseline activity level; 770 hours or $2.31 million at Future 1; and 3,010 hours or $10.66 million at Future 2.

4a. Extend Runway 18R/36L to Taxiway A.

There are no direct delay savings benefits from this alternative. However, it should enhance MEM's capability to attract operations requiring non-stop, long range flights and compliment the extension of Runway 18C/36C.

The estimated project cost is $350 million.

4b. Extend Taxiway M to Taxiway V.

Currently there is only one taxiway on the west side of the airport which crosses Winchester Road. A second taxiway crossing Winchester Road would prevent bottlenecks and circuitous taxi routing. This improvement will provide two parallel taxiways to Runway 18R/36L and allow appropriate directional flows to the extended runway. This alternative will reduce congestion on Taxiway N at the end of Runway 18R and at the main terminal area.

The estimated project cost is $25 million.

Annual delay savings would be 830 hours or $1.99 million at the Baseline activity level; 1,710 hours or $5.12 million at Future 1; and 8,210 hours or $29.06 million at Future 2.

4c. Construct a New Taxiway M7 from Exit M7 to Taxiway C at Exit D.

This taxiway will be a long, cross-field taxiway south of Winchester Road facilitating access between parallel runway thresholds. This improvement will primarily serve passenger aircraft in the vicinity of the terminal. It should be helpful in building departure queues and shortening taxi times to/from parking gates. This alternative will require the construction of a new control tower. Additionally, it could require three overpass structures, retaining walls, and potential replacement of the parking garage.

The estimated project cost is $100 million.

Annual delay savings would be 00 hours or $00 million at the Baseline activity level; 680 hours or $2.05 million at Future 1; and 4,230 hours or $14.98 million at Future 2.

5. High Speed Exits in Both Flow Directions on Runways 18R/36L, 18C/36C, 18L/36R and 9/27 with Reduced Occupancy Times (50 secs) to Support Reduced Longitudinal Spacing (Item 24). Additionally, Consider High Speed Exits on Runway 18L/36R on Both Sides (East and West) of the Runway.

Space permitting, high speed exits on both sides of a runway yield significant benefits in reduced runway occupancy times and contribute to increased capacity. They support reduced longitudinal separations of IFR arrivals.

The estimated project cost is $6.7 million (set of four).

Annual delay savings would be 210 hours or $.50 million at the Baseline activity level; 760 hours or $2.27 million at Future 1; and 2,550 hours or $9.01 million at Future 2.

6. During Reconstruction of Runway 18R/36L:

a. Operate Extended Taxiway N as a 5,000' Commuter/GA Runway in VFR Only. Use for Arrivals in North Flow and Departures in South Flow.

To minimize the effect of closing Runway 18R/36L during reconstruction, it is desirable to identify an alternative temporary runway which could be placed in service and, within assigned safe limits, improve the operational capacity of the airport until normal operations can be resumed. This alternative represents one possibility. Use would have to be restricted to arrivals in north flow and departures in south flow to avoid adverse impact on terminal area operations.

The estimated project cost is $500,000.

Annual delay savings would be 530 hours or $1.28 million at the Baseline activity level; 4,270 hours or $12.8 million at Future 1; and 7,240 hours or $25.61 million at Future 2.

These savings are reductions of delay costs associated with the closing of Runway 18R/36L.

b. Operate Taxiway M as a 9,000' Air Carrier Runway - ARR and DEP in Both North and South Flows in VFR Only (Aircraft Limited to Maximum Wingspan of 108 ft (B-727-200)).

To minimize the effect of closing Runway 18R/36L during reconstruction, it is desirable to identify an alternative runway which could be placed in service and, within assigned safe limits, improve the operational capacity of the airport until normal operations can be resumed. This alternative represents one possibility. This alternative requires the extension of Taxiway N to the south for runway access (See Alternative 3 above). Use would be restricted to aircraft having a maximum wingspan of 108 feet (B727-200) to ensure an acceptable level of safety.

The estimated project cost is $2 million for Taxiway M.

Annual delay savings would be 1,280 hours or $3.07 million at the Baseline activity level; 12,680 hours or $38.02 million at Future 1; and 31,380 hours or $111.05 million at Future 2.

These savings are reductions of delay costs associated with the closing of Runway 18R/36L.

7. Construct By-pass Taxiway on North Side at Runway 27 End.

Runway 27 has a single connecting taxiway on each side at the runway threshold. Consequently, the traffic utilizing those taxiways is heavy, whether crossing to the other side or accessing the runway itself. Construction of a by-pass taxiway on the north side of Runway 27 end will reduce delays by allowing direct access to Runway 27. Additionally, it provides a separate cross-over route to Taxiway A.

The estimated project cost is $8 million.

Annual delay savings would be 00 hours or $00 million at the Baseline activity level; 880 hours or $2.65 million at Future 1; and 2,930 hours or $10.38 million at Future 2.

8. Terminal Expansion.

Expanding the terminal to include maximizing existing parking gates and constructing new gates will require larger holdrooms at some existing gates, new holdrooms, baggage claim and make-up areas, parking aprons, restrooms, shops, and other passenger amenities.

The estimated project cost is $150 million.

Analyzing the delay savings of this improvement was beyond the scope of this study.

9. Develop Area (500 Acres) East of Runway 18L/36R for Cargo and Maintenance Facilities.

Aircraft access to airport-owned property east of Runway 18L/36R will require constructing taxiway connections to Taxiway Y. Adequate public roadways and utility service is available adjacent to the property. Additional facilities to be provided would depend upon the type of tenant development.

The estimated project cost is $20 million.

This improvement provides no direct delay savings benefits, but would enhance the capability of MEM to attract additional cargo and maintenance operators.

10. Establish Deicing Facility Between Runways 36L and 36C at South End on Crossover Taxiways H and R.

It has been estimated that maximum runway use during peak periods of aircraft deicing can be achieved by providing nine widebody deicing spaces at the south end of the parallel runways. This would require a large pad oriented east/west that links holding aprons at the ends of Runway 36C and Runway 36L. Overspray would be collected for appropriate disposal by a drain system.

The estimated project cost is $26 million.

This improvement was not simulated because the Design Team determined that the expected delay savings benefit would not justify the effort required to develop model inputs.

11. Establish Departure Staging Areas (Staging of 2, 3, 4, or 5 Aircraft) at All Runway Ends.

Runways 36L (and 18R when using Taxiway N) presently have departure staging areas near the threshold, allowing the ATCT some ability to re-sequence departing aircraft from their place in the queue. In order to reduce departure queue delays, other runways are programmed for construction of staging areas as reconstruction phasing allows.

The estimated project cost is: 2 spaces - $5 million; 3 spaces - $7.5 million; 4 spaces - $10 million; 5 spaces - $12.5 million.

This improvement was not simulated because the Design Team determined that the expected delay savings benefit would not justify the effort required to develop model inputs.

Facilities and Equipment Improvements

12. Category IIIc, less than 600' RVR, Approaches - Runways 36R and 36L.

This improvement would allow simultaneous independent approaches to Runways 36L and 36R during periods of low visibility conditions with less than 600' RVR. The Design Team estimates that these conditions occur about 22 hours per year. During these conditions, the airport is currently shut down. This improvement would allow the airport to remain open, thus significantly reducing delays.

The improvement would include additional pavement marking and lighting and revisions to the airport's Surface Movement Guidance and Control System (SMGCS) Plan.

The estimated project cost is unavailable.

This improvement was not simulated because the Design Team determined that the expected delay savings benefit would not justify the effort required to develop model inputs.

13. Precision Runway Monitor (PRM), Final Monitors/Aids (FMA):

Where closely-spaced parallel runways exist, the proximity of arrival paths precludes independent parallel instrument approaches using conventional radar systems when weather conditions are less than the required minimum for visual approaches. The PRM is a new high-update radar system that allows independent parallel instrument approaches to closely-spaced parallel runways during these conditions. Demonstrations of PRM technology resulted in the publication of procedures for independent parallel instrument approaches to runways having centerlines separated by 3,000 feet or more.

The FMA is a high resolution color display which is equipped with the controller alert hardware and software used in the PRM system. The display includes alert algorithms which provide aircraft track predictors, a color change alert when an aircraft penetrates or is predicted to penetrate the no transgression zone (NTZ), a color change alert if the aircraft transponder becomes inoperative, and digital mapping.

This improvement would allow independent approaches to Runways 18R and 18C, and 36L and 36C, if Runway 18L/36R is out of service. However, it is not expected that Runway 18L/36R will be out of service for any extended period of time. Please note that the delay savings depicted are computed on an annual basis.

The estimated project cost is $7.0 million.

Annual delay savings would be 1,410 hours or $3.4 million at the Baseline activity level; 4,240 hours or $12.73 million at Future 1; and 6,230 hours or $22.06 million at Future 2.

The delay savings benefits are based on a comparison of the delay costs with and without the PRM, assuming Runway 18L/36R being out of service.

14. Integrated Terminal Weather System (ITWS).

The ITWS is an upgrade to the current Doppler weather radar. The ITWS — a fully automated, integrated terminal weather information system — will improve safety, efficiency, and capacity of terminal area aviation operations. The system, which is designed to integrate weather data from FAA and National Weather Service (NWS) sensors located in the terminal area, will provide near-term weather predictions and depiction in easily understood graphical and textual formats for air traffic personnel. Benefits to users over the 20-year life cycle of the system are estimated to be more than $6 billion.

The ITWS situation displays will be located in tower cabs, terminal radar approach control facilities, and associated air route traffic control centers. The system will be critically important in the takeoff and landing phases of flight, and during hazardous weather.

The first production ITWS is scheduled to become operational in MEM in November 2001.

The estimated project cost is unavailable.

15. Wake Vortex Advisory System (WVAS).

Under current conditions, air traffic controllers cannot detect the presence of wake vortices. Therefore, to guard against these potential hazards, increased separations between aircraft are maintained. The Wake Vortex Advisory System (WVAS) would increase capacity by permitting reduced spacing between aircraft when wake vortices present no hazards to following aircraft. It is anticipated that joint FAA and

National Aeronautics and Space Administration (NASA) efforts, using a radar type sensing technology named the Automated Vortex Sensing System (AVSS), will yield an operational system by 1998.

The estimated project cost is unavailable.

a. No Wake Vortices Detected 50% of the Time.

Annual delay savings would be 230 hours or $.54 million at the Baseline activity level; 1,320 hours or $3.96 million at Future 1; and 3,200 hours or $11.30 million at Future 2.

b. No Wake Vortices Detected 100 % of the Time.

Annual delay savings would be 450 hours or $1.07 million at the Baseline activity level; 2,640 hours or $7.92 million at Future 1; and 6,390 hours or $22.60 million at Future 2.

16. Center-TRACON Automation System (CTAS).

The CTAS is designed to improve system performance (e.g., efficiency, capacity, controller workload), while maintaining at least the same level of safety present in today's system, by helping the controller smooth out and coordinate traffic flow efficiently. The earliest CTAS tool is the Traffic Management Advisor (TMA), with one TMA specifically designed for the Center environment (CTMA) and one for the TRACON (TTMA). The TMA determines the optimum sequence and schedule for arrival traffic, and coordination between air traffic control facilities such as an ARTCC and a TRACON is managed via the TMAs for the respective facility. TMA provides ARTCC controllers and traffic management controllers (TMCS) with arrival metering times for individual aircraft to meet at TRACON feeder gates. If the controllers/pilots meet these times, the flow to the TRACON is made more consistent and excess delays are avoided. In addition, any required delays can be absorbed earlier, i.e. at higher altitudes, at a lower cost to the airline than low-altitude delays. The next tool for the CTAS will be the Final Approach Spacing Tool (FAST) for the TRACON. FAST aids TRACON controllers in merging arrival traffic into an efficient flow to the final approach path and also supports controllers in efficiently merging missed approach and pop-up traffic into the final approach stream. A passive system, fast provides controllers with recommended runway assignments and sequences which facilitate improved airport utilization during rushes.

The redevelopment contract for CTAS has been awarded and it is anticipated that the first deployment will occur in late 2000.

The estimated project cost is unavailable.

Operational Improvements

17. Converging Arrivals on Runways 18L, 18R, and 27 Using the Converging Runway Display Aid (CRDA) — With Unrestricted Use of Rwy 27 in VFR.

The CRDA displays an aircraft at its actual location and simultaneously displays its image at another location on the controller's scope to assist the controller in assessing the relative positions of aircraft that are on different approach paths.

This alternative was modeled using VFR conditions with all category aircraft utilizing Runway 27. Modeling results indicated negative savings. However, if land and hold short (LAHSO) procedures were implemented for Runway 27, CRDA could prove beneficial in VFR conditions.

CRDA may also increase airport capacity if the east parallel is closed and the active runways are 18R and 27 during IFR conditions (not modeled). Furthermore, the use of CRDA would eliminate the Class 1, 2 and 3 aircraft restrictions on Runway 9/27 during VFR conditions.

18. Reduce Longitudinal In-Trail Spacing to 2.5 NM in IFR.

Reducing separation minimums to 2.5 NM for aircraft of similar class within 10 NM of the runway would increase arrival rates and runway capacity. Aircraft capable of takeoff weights of 300,000 pounds or more and the Boeing 757 may participate in the separation reduction as trailing aircraft only. Most of the delay savings occur at the highest demand levels under IFR. In order to use reduced final approach in-trail separations, it must be demonstrated that runway occupancy times for arrivals are consistently 50 seconds or less.

Annual delay savings would be 790 hours or $1.9 million at the Baseline activity level; 2,410 hours or $7.23 million at Future 1; and 4,940 hours or $17.49 million at Future 2.

19. Simultaneous Parallel Departures on Runways 18R and 18C in Non-visual Conditions (Less Than 5,000' Ceiling and/or 5 Miles Visibility) Assuming Flight Procedures Allow Departures to Diverge by 15 Degrees Immediately after Take Off.

Presently, simultaneous parallel departures on Runways 18R and 18C are not allowed in non-visual conditions. Operations are conducted with a 1 mile stagger and a 15 degree diverging turn at 4 miles. This does not allow departures to diverge immediately after take off. If the noise abatement procedures were removed, aircraft could diverge immediately after take-off and simultaneous departures could occur. Thus, capacity would be increased.

Annual delay savings would be 60 hours or $.15 million at the Baseline activity level; 150 hours or $.44 million at Future 1; and 300 hours or $1.04 million at Future 2.

20. Triple Simultaneous Parallel Departures in South Flow:

Noise abatement procedures departing to the south currently do not allow diverging departures in IFR. If noise abatement procedures were removed, departures could diverge immediately after take off during IFR conditions.

a. Rwys 18R, 18C, and 18L Without Rwy 27 (Without Noise Abatement).

Annual delay savings (costs) would be (3,730) hours or ($8.94) million at the Baseline activity level; (13,550) hours or ($40.65) million at Future 1; and 33,520 hours or ($118.66) million at Future 2.

b. Rwys 18R, 18C, and 18L With Rwy 27 (Without Noise Abatement).

The Design Team recognizes that removing the existing noise abatement procedures would require a determination of the community impact; therefore, it is recommended that further study be made of this improvement.

Annual delay savings would be 310 hours or $.76 million at the Baseline activity level; 4,460 hours or $13.37 million at Future 1; and 2,310 hours or $8.17 million at Future 2.

21. Runway Operations During Reconstruction of Runways 18R/36L, 18C/36C, and 9/27:

During the course of this study, the Design Team determined that the useful life of Runways 18R/36L, 18C/36C and 9/27 will be exceeded in the not too distant future. Operational necessity requires that reconstruction of these runways take place individually over several years. Therefore, the alternatives reflected below were examined to enhance the Airport Authority's construction planning process.

a. Runway 18C/36C Closed, Runways 18R/36L, 18L/36R and 9/27 Operational.

Annual delay savings (costs) would be (1,060) hours or ($2.54) million at the Baseline activity level; (6,530) hours or ($19.6) million at Future 1; and (14,420) hours or ($51.06) million at Future 2.

b. Runway 18R/36L Closed, Runways 18C/36C, 18L/36R, and 9/27 Operational.

Annual delay savings (costs) would be (10,950) hours or ($26.27) million at the Baseline activity level; (41,820) hours or ($125.45) million at Future 1; and (93,320) hours or ($330.34) million at Future 2.

c. Runway 18R/36L Closed, Runways 18C/36C, 18L/36R, and 9/27 Operational With (Note: Delay Savings are Based on a Comparison with Alternative 27b):

i. Taxiway N as a Temporary Commuter/GA Runway in VFR Only (ARR North Flow, DEP South Flow).

Annual delay savings would be 530 hours or $1.28 million at the Baseline activity level; 4,270 hours or $12.8 million at Future 1; and 7,240 hours or $25.61 million at Future 2.

These delay savings are reductions of delay costs associated with the closing of Runway 18R/36L.

c. Runway 18R/36L Closed, Runways 18C/36C, 18L/36R, and 9/27 Operational With (Note: Delay Savings are Based on a Comparison with Alternative 27b):

ii. Taxiway M as a Temporary Air Carrier Runway - ARR and DEP in North and South Flow in VFR Only (Aircraft Limited to Maximum Wingspan of 108 ft (B-727-200)).

Annual delay savings would be 1,280 hours or $3.07 million at the Baseline activity level; 12,680 hours or $38.02 million at Future 1; and 31,380 hours or $111.05 million at Future 2.

These delay savings are reductions of delay costs associated with the closing of Runway 18R/36L.

d. Runway 9/27 Closed - Runways 18R/36L, 18C/36C, and 18L/36R Operational.

Annual delay savings (costs) would be (7,130) hours or ($17.1) million at the Baseline activity level; (26,000) hours or ($78.01) million at Future 1; and (59,970) hours or ($212.3) million at Future 2.

e. Runways 18C/36C and 18R/36L Closed - Runways 9/27 and 18L/36R Operational.

Annual delay savings (costs) would be (23,040) hours or ($55.29) million at the Baseline activity level; (89,700) hours or ($269.1) million at Future 1; and (154,400) hours or ($546.58) million at Future 2.

User or Policy Improvements

22. Uniformly Distribute Scheduled Commercial Operations Within the Hour.

A more uniform distribution of airline flights during peak periods would promote a more orderly flow of traffic, reduce arrival and departure delays, and reduce ground congestion near the terminal and on the taxiway system.

However, mem is part of a hub-and-spoke operation, and uniform distribution of traffic is not consistent with such an operation. Hubbing creates efficiencies that cannot be measured in a delay study of this type. This system of operations provides frequent service between city-pairs that could not support frequent direct service. Under the hub and spoke system, air service is provided to some cities that may not otherwise receive it. Frequent flights provide an economic benefit to consumers, in particular the business flyer. Therefore, the Design Team does not recommend that this improvement be implemented.

23. Enhancement of the Reliever and GA Airport System.

Reliever and GA airports can ease capacity constraints by attracting small/slow aircraft away from primary airports, especially where small/slow aircraft constitute a significant portion of operations. The segregation of aircraft operations by size and speed increases effective capacity because required time and distance separations are reduced between planes of similar size and speed.

The Design Team recommends the continuing development and enhancement of the reliever and GA airport system around MEM.

Section 3

Summary of Technical Studies

Overview

The Memphis International Airport Capacity Design Team evaluated the efficiency of the existing airfield and the proposed future configurations. A brief description of the computer models and methodology used can be found in Appendix B. Certain standard inputs were used to reflect the operating environment at MEM. Details can be found in the data packages produced by the Federal Aviation Administration Technical Center during the study. The potential benefits of various improvements were determined by examining airfield capacity, airfield demand, and average aircraft delays and travel times.

Figure 4 shows current airfield weather conditions. Figure 5 defines aircraft classes operating at MEM. Figure 6 breaks down the annual traffic distribution by aircraft category for each demand level. Figure 7 shows the aircraft approach speeds used for simulation. Figure 8 depicts the length of common approach in nautical miles by class of aircraft while Figure 9 shows the departure runway occupancy times in seconds by class of aircraft. Figure 10 presents Memphis daily traffic for the Baseline, Future 1 and Future 2 operations levels by class of aircraft while Figure 11 presents the same information broken down by type of operation.

Delays were calculated for current and future conditions. Daily delays were annualized using a value of 320 equivalent days for all three demand levels. The annualized delays provided a basis for determining the benefits of the proposed improvements. Unless otherwise noted, the annualized delay of each improvement was subtracted from the annualized delay for the “Do Nothing” case to determine its benefit in terms of delay savings. Daily operations corresponding to an average day in the peak month were used for each of the forecast periods.

The MEM aircraft fleet mix weighted-average direct operating cost, in 1997 dollars, for the baseline is $2,400.00 per hour, or $40.00 per minute; for Future 1, the operating cost is $3,000.00 per hour or $50.00 per minute; for Future 2, the operating cost is $3,540.00 per hour or $59.00 per minute. These figures are based on the Memphis daily traffic sample, type of aircraft distribution and operating cost data for scheduled and non-scheduled operations. They represent the costs for operating the aircraft and include such items as fuel, maintenance, and crew costs, but they do not consider lost passenger time, disruption to airline schedules, or other non-traditional factors.

For expected increases in demand, a combination of improvements can be implemented to allow airfield capacity to increase while aircraft delays are minimized.

Figure 4. Airfield Weather

Operations	Visibility/Ceiling	Occurrence
VFR	5 miles/5,000 ft and above	77.1%
IFR-1	2 miles/700 ft to 5 miles/5,000 ft	17.3%
IFR-2	1 mile/400 ft to 2 miles/700 ft	3.9%
IFR-3	0.5 miles/200 feet to 1 mile/400 ft	1.2%
IFR-4	Less than 0.5 miles/200 ft	0.5%

Figure 5. Aircraft Class Definitions

The MEM Design Team, in order to facilitate comparison of the 1997 study simulation results with the 1988 study, utilized aircraft class weight designations in effect at the time of the 1988 study.

Original Aircraft Class	New Aircraft Class	Aircraft Types
D(1)	1	Heavy Aircraft weighing more than 300,000 lbs (e.g., A300, B707 - 300 - 400 Series, B747, B767, Concorde, DC8S, IL62, L1011)
C(2)	2	Large B757 - Special class aircraft
C(2)	3	Large aircraft weighing more than 100,000 and up to 300,000 lbs (e.g., B737, B727, DC9, MD88)
C(2)	4	Large aircraft (Small jets and props) weighing more than 12,500 lbs and up to 100,000 lbs (AT72, BA31, C560, FK27, LR35, EM2, SF34)
B(3)	5	Small, twin-engine aircraft (props) weighing 12,500 lbs or less (e.g., BE55, BE58, C12, C26A, C414, C421, D08, P180, PA31, PAZ, U21)
A(4)	6	Small, single-engine aircraft (props) weighing 12,500 lbs or less (e.g., C208, C210, 172RG)

Notes:

a. For aircraft designator, see FAA Handbook 7340.1E with changes.

b. Weights refer to maximum certified takeoff weights.

c. Heavy aircraft are capable of takeoff weights of 300,000 pounds or more, whether or not they are operating at this weight during a particular phase of flight (reference FAA Handbook 7110.65 with changes)

d. Class 4 is specifically identified as small jets and props that can be accommodated at Memphis on an available 5,000' of runway length.

Figure 6. Annual Operations by Aircraft Category

	Air Carrier	Air Taxi	Int.	General Aviation	Military	Cargo	Total
Baseline	105,600	81,000	3,000	80,000	6,000	84,400	360,000
Percent	29.34%	22.51%	0.82%	22.26%	1.63%	23.46%	100%
Future 1	118,000	103,300	1,800	87,000	5,900	140,000	456,000
Percent	25.88%	22.65%	0.39%	19.08%	1.30%	30.70%	100%
Future 2	113,800	117,200	3,200	95,900	5,900	198,000	534,000
Percent	21.31%	21.95%	0.60%	17.96%	1.10%	37.08%	100%

Based on Memphis International Airport 1995 Activity Report and the Master Plan Update Activity Forecast, Greiner Inc. Revised July 1996.

Figure 7. Aircraft Approach Speeds (knots)

Class	1	2	3	4	5	6
VFR	150	140	150	140	120	110
IFR	140	130	130	130	120	110

Figure 8. Length of Common Approach (nautical miles)

Class	1	2	3	4	5	6
VFR	5	5	5	5	5	5
IFR	5	5	5	5	5	5

Figure 9. Departure Runway Occupancy Times* (seconds)

Class	1	2	3	4	5	6
Seconds	33	24	29	29	23	23

* Average time Roll to Liftoff

Figure 10. Memphis Daily Traffic - By Class of Aircraft

Class	1	2	3	4	5	6	Total
Baseline	120	16	520	280	100	90	1,126
Future 1	310	36	532	340	114	94	1,426
Future 2	600	64	440	350	116	100	1,670

Figure 11. Memphis Daily Traffic - By Type of Operation

Operation	Air Carrier	Commuter	Cargo	GA	Mil	Total Daily Ops
Baseline	310	236	340	220	20	1,126
Future 1	330	300	542	234	20	1,426
Future 2	310	330	760	250	20	1,670

Airfield Capacity

The MEM Design Team defined airfield capacity to be the maximum number of aircraft operations (landings or takeoffs) that can take place in a given time under given conditions. The following conditions were considered:

- Level of Delay
- Airspace constraints
- Ceiling and visibility conditions
- Runway layout and use
- Aircraft mix
- Percent arrival demand
- Day and night operations

Figure 12 illustrates the average-day, peak-month demand levels for MEM for each of the three annual activity levels used in the study, Baseline, Future 1 and Future 2. Figure 13 illustrates the hourly profile of daily demand for the Baseline activity level. For comparison, it also includes curves depicting the profile of daily operations for the Future 1 and 2 activity levels. Figure 14 graphically illustrates runway utilization during north and south flow with day, night, IFR and VFR conditions.

Figure 12. Airfield Demand Levels

	Annual Operations	24-Hour Day (average day, peak month)	Equivalent Days
Baseline	360,000	1,126	320
Future 1	456,000	1,426	320
Future 2	534,000	1,670	320

Figure 13. Profile of Daily Demand - Hourly Distribution

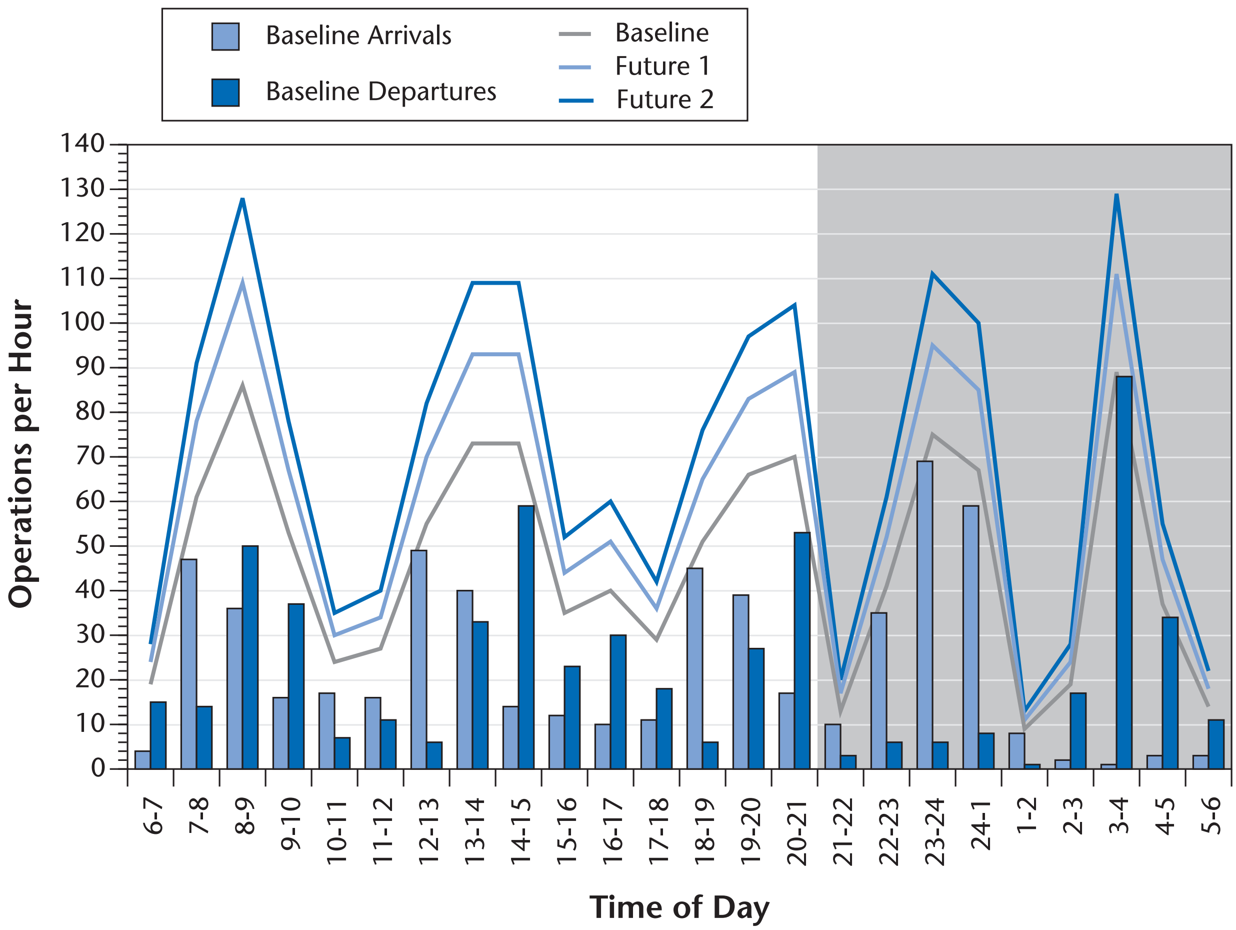
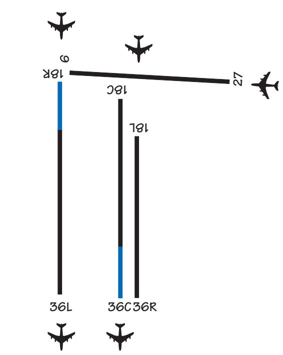


Figure 14. Memphis Configurations - Three Parallel Runways

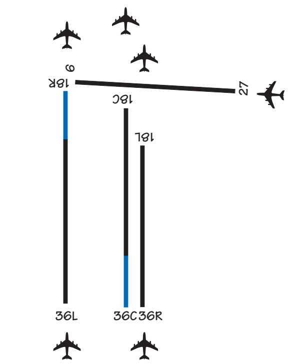
3a. Day - VFR, IFR1

Arr = 18R, 18L, 27
Dep = 18C, 18R



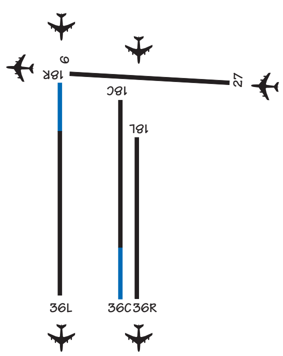
4a. Day - VFR, IFR1, IFR2
Night - VFR, IFR1, IFR2, IFR3

Arr = 27, 36R, 36L
Dep = 36C, 36R, 36L



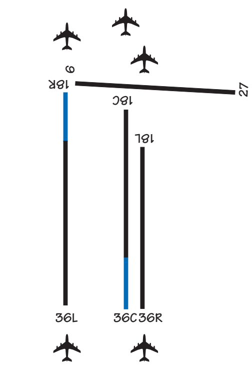
3b. Night - VFR, IFR1, IFR2

Arr = 18R, 18L, 27
Dep = 18R, 18L, 27



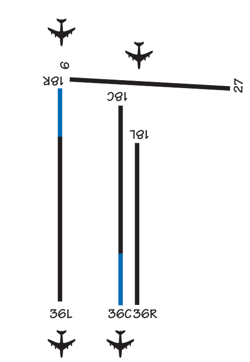
4b. Day - IFR3, IFR4
Night - IFR4

Arr = 36R, 36L
Dep = 36C, 36R, 36L



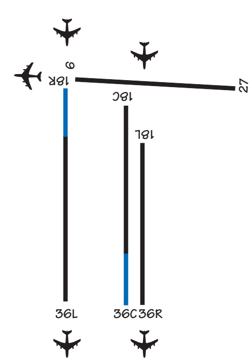
3c. Day - IFR2, IFR3

Arr = 18R, 18L
Dep = 18C, 18R



4c. Night - IFR3

Arr = 18R, 18L
Dep = 18R, 18L, 27



The curves in Figures 15 and 16 illustrate the relationship between airfield capacity, stated in the numbers of operations per hour, and the average delay per aircraft. As the number of aircraft operations per hour increases, the average delay per operation increases exponentially.

These curves also illustrate that, at Memphis, there is a great variation in airfield capacity between the north and south flows, between day and night operations, during arrival and departure pushes, and with varying weather conditions.

A comparison of the information presented in Figures 13, 15, and 16 shows that:

- Aircraft delays, in north or south flows, day or night, depending on type of demand push, will begin to rapidly escalate as hourly demand exceeds airfield capacity in IFR conditions; and,
- While hourly demand may exceed airfield capacity only during certain hours of the day at the Baseline demand level, airfield capacity is frequently exceeded at future demand levels.

Aircraft Delays

Aircraft delay is defined as the time above the unimpeded travel time for an aircraft to move from its origin to its destination. Aircraft delay results from interference from other aircraft competing for the use of the same facilities.

The major factors influencing aircraft delays are:

- Ceiling and visibility conditions
- Airfield and atc system demand
- Airfield physical characteristics
- Air traffic control procedures
- Aircraft operational characteristics

Total daily delays in minutes were generated either by the Runway Delay Simulation Model (RDSIM) or the Airfield Delay Simulation Model (ADSIM) and annualized. These models are described in Appendix B.

If no improvements are made in airport capacity, the annual delay of 10,640 hours at the Baseline level of operations will increase to 33,670 hours by Future 1 and 64,030 hours by Future 2. Under this Do Nothing scenario (no improvements in airfield capacity with no gate capacity constraints), the annual delay costs are predicted to increase as shown in Figure 17.

Figure 15. Airport Capacity Curves - Hourly Flow Rate Versus Average Delay Existing Airfield - Three Parallel Runways - South Flow

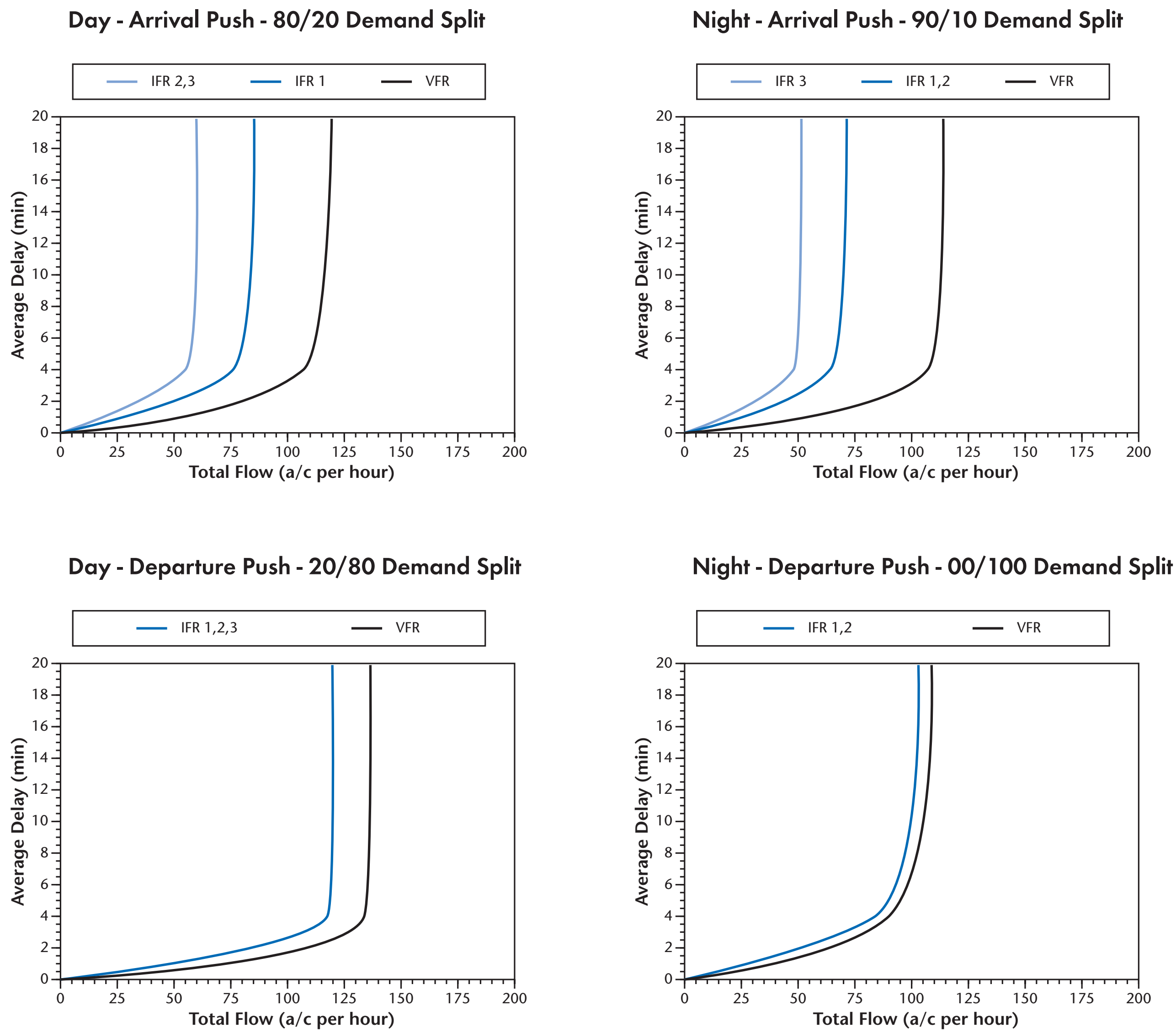


Figure 16. Airport Capacity Curves - Hourly Flow Rate Versus Average Delay Existing Airfield - Three Parallel Runways - North Flow

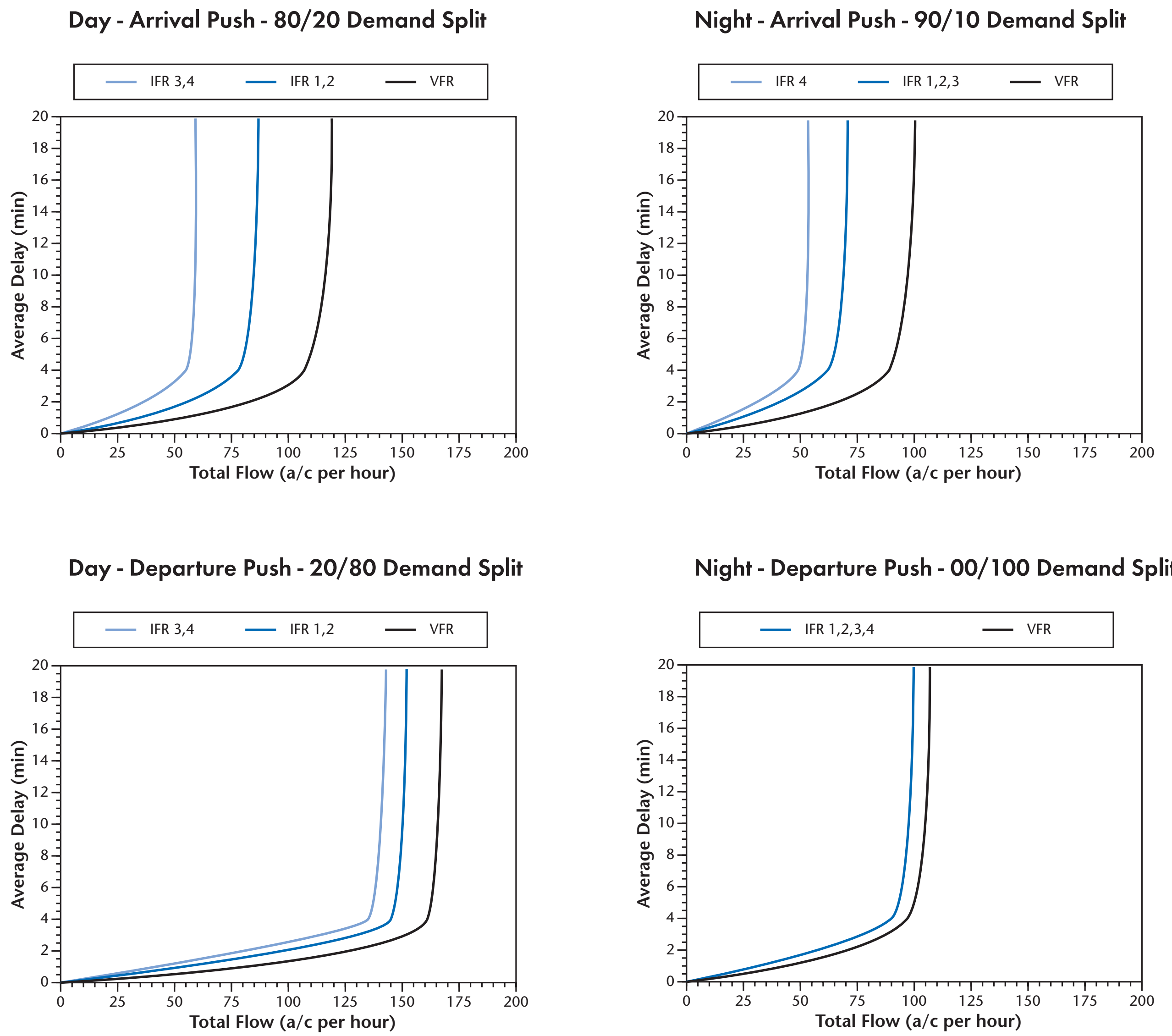
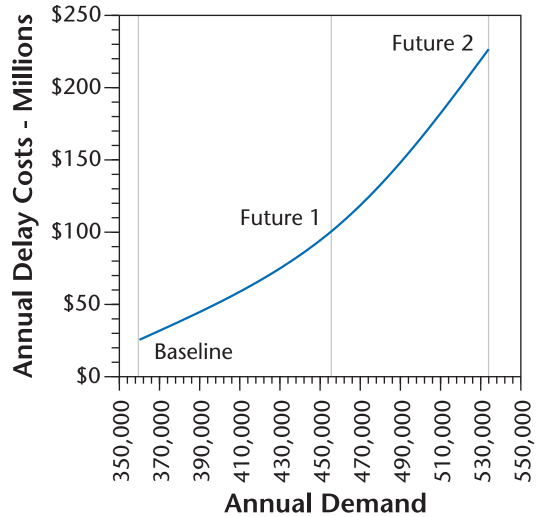


Figure 17. Annual Delay Costs

	Annual Delay Costs Hours	Min/Op	Millions of $
Baseline	10,640	1.8	$25.54
Future 1	33,670	4.4	$101.01
Future 2	64,030	7.2	$226.66



Conclusions

Based on the analysis completed during the study, the Design Team recommended the following major capacity enhancement alternatives:

Airfield Improvements

- Extend Runway 18C/36C to the south to 11,100 ft to accommodate non-stop long range flights.
- Construct by-pass taxiway on north side at Runway 27 end.
- During reconstruction of Runway 18R/36L, operate Taxiway M as an air carrier runway with arrivals and departures in north and south flow in VFR only.
- Extend Taxiway N to the full length of existing Runway 18R/36L to provide improved access to Runway 36L and provide temporary service to Taxiway M while being utilized as an active runway.
- Extend outer Taxiway Y east of and parallel to Runway 18L/36R.
- Extend Taxiway C to extended Runway 36C's end.

Facilities and Equipment Improvements

- Obtain precision runway monitor (PRM) final monitors/aids (FMA).
- Obtain wake vortex advisory system (WVAS).

Operational Improvements

- Reduce longitudinal in-trail spacing to 2.5 nm in IFR.

Appendix A

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Appendix B

Computer Models and Methodology

The Memphis Design Team studied the effects of various improvements proposed to reduce delay and enhance capacity. The options were evaluated considering the anticipated increase in demand. The analysis was performed using computer modeling techniques. A brief description of the models and the methodology employed follows.

Computer Models

Airfield Delay Simulation Model (ADSIM)

The Airfield Delay Simulation Model is a fast-time, discrete event model that employs stochastic processes and Monte Carlo sampling techniques. It describes significant movements of aircraft on the airport and the effects of delay in the adjacent airspace. The model was validated in 1978 at Chicago O'Hare International Airport against actual flow rates and delay data. It was calibrated for this study against field data collected at MEM to insure that the model was site specific.

Inputs for the simulation model were derived from empirical field data. The model repeated each experiment 10 times using Monte Carlo sampling techniques to introduce system variability, which occurs on a daily basis in actual airport operations. The results were averaged to produce output statistics. Total and hourly aircraft delays, travel times, and flow rates for the airport and for the individual runways were calculated.

Runway Delay Simulation Model (RDSIM)

The Runway Delay Simulation Model is a short version of the Airfield Delay Simulation Model. RDSIM simulates only the runways and runway exits and adjacent airspace. There are two versions of the model. The first version ignores the taxiway and gate complexes for a user-specified daily traffic demand and is used to calculate daily demand statistics. In this mode, the model replicates each experiment forty times, using Monte Carlo sampling techniques to introduce system variability, which occurs on a daily basis in actual airport operations. The results are averaged to produce output statistics. The second version also simulates the runway and runway exits only, but it creates its own demand using randomly assigned arrival and departure times.

The demand created is based upon user-specified parameters. This form of the model is suitable for capacity analysis.

For this study, RDSIM was calibrated against field data collected at MEM to ensure that the model was site specific. For a given demand, the model calculated the hourly flow rate and average delay per aircraft during the full period of airport operations. Using the same aircraft mix, simulation analysts simulated different demand levels for each run to generate demand versus delay relationships.

Methodology

Model simulations included present and future air traffic control procedures, various airfield improvements, and traffic demands for different times. To assess the benefits of proposed airfield improvements, different airfield configurations were derived from present and projected airport layouts. The projected implementation time for air traffic control procedures and system improvements determined the aircraft separations used for IFR and VFR weather simulations.

For the delay analysis, agency specialists developed traffic demands based on the Official Airline Guide, historical data, and various forecasts. Aircraft volume, mix and peaking characteristics were developed for four demand periods, Baseline, Future 1 and Future 2. The estimated annual delays for the proposed improvement options were calculated from the experimental results. These estimates took into account the yearly variations in runway configurations, weather, and demand based on historical data.

The potential delay reductions for each improvement were assessed by comparing its annual delay estimates with the delay estimates for the Do Nothing or Baseline case except as otherwise noted.

Appendix C

List of Abbreviations

ADSIM	Airfield Delay Simulation Model
ARTCC	Air Route Traffic Control Center
ASC	Office of System Capacity, fAA
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
CAT	Category — of instrument landing system
CRDA	Converging Runway Display Aid
CTAS	Center-TRACON Automation System
FAA	Federal Aviation Administration
FAST	Final Approach Spacing Tool
FMA	Final Monitor Aid
GA	General Aviation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
ITWS	Integrated Terminal Weather System
LAHSO	Land and Hold Short Operations
LBS	Pounds
MEM	Memphis International Airport
MMSA	Memphis Metropolitan Statistical Area
NM	Nautical Miles
NWS	National Weather Service
RDSIM	Runway Delay Simulation Model
ROT	Runway Occupancy Time
RVR	Runway Visual Range
SIMMOD	Airport and Airspace Simulation Model
SM	Statute Miles
SMGCS	Surface Movement Guidance and Control System
TMA	Traffic Management Advisor
TMC	Traffic Management Controller
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
WVAS	Wake Vortex Advisory System

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